ACOUSTICAL DATA IN A GENERAL WEAPON DATABASE

Karl-Wilhelm Hirsch
Mattias Trimpop

Institut für Lärmschutz, Düsseldorf

INTRODUCTION

According to a preliminary German regulation on the prediction and assessment of shooting noise in the vicinity of military training areas /1/, the noise load for a single event i is given by a simple empirical formula

$$L_i = S_i + R_i - 20\log(r/r_0) + A_i \log(r/r_0) + B_i(r/r_0) + C_i \ldots \qquad \text{eq. (1)}$$

In eq. 1, let denote L the single event level, S the source level at 250 m, R the directivity and A, B and C some more coefficients in additional terms. All coefficients indicated with i are specific to the source under consideration, that means they are specific to each combination of weapon-system, weapon and ammunition. This is necessary because the directivity is defined in the horizontal plane and the construction of the weapon system and the particular use of the weapon will influence sound radiation also with respect to elevation. That means that a cannon mounted on a tank firing anti aircraft missions will sound different compared to the same weapon if hand held and fighting targets at the ground.

This model /1/ predicts the long term average noise load for the yearly events from all installations on the training area with all weapon ammunition combinations. Considering the capabilities of computers, such a simple model was needed, 10 years ago, to archive results for a large area. Even with this model, the calculation of noise contours took a week then to complete a map for the vicinity (about 500 km²) of a large training area (800 different sources). However, in hilly terrain and for special weather conditions, the model is known to give too high levels due to the missing shielding term and a more sophisticated weather term, respectively.

Since the early 90's, there has been much progress so far computers are concerned. Using modern computers, this model yields acceptable results for the assessment of shooting noise with respect to its purpose in terms of minutes. Today, there is also much more knowledge about the description of blast sources and about propagation of sound through the atmosphere. In a special session during the last DAGA conference /2/, many presentations indicated the recent progress in this field. However all the contributions yield one common practical result: the numerical afford of calculation increases rapidly if physical methods are applied to sound propagation outdoors.

There is today also a deeper understanding of the effect of coherence of blast sound at the receiver. The superposition of direct sound and the always present ground reflection at the receiver strongly effects the spectrum of sound and therefore changes the difference between A-weighted levels and C-weighted levels. The sound generation of blast sources is now better understood. There are simple models available that give reliable estimations of the spectrum of the blast even on the basis of poor input data.

As a conclusion, there is a chance to improve the prediction model considering this progress. However, all the source and propagation data for the model /1/ were collected in terms of a source CSEL at a distance of 250 m and a directivity pattern with respect to this acoustical weighting. These data were acquired during measuring sessions in Germany; but also results from measurements in the UK and the US are used. These source measurements were conducted according to a test plan that the international Ad Hoc Working Group of Low Frequency Noise established in 1996, /3/.

ESTIMATION OF THE ONE-THIRD OCTAVE SPECTRUM OF A BLAST

Such source measurements with heavy weapons are expensive and it would be difficult to repeat these experiments. It is clear however, that the physical improvements for instance with respect to terrain shielding need more detailed input data, in particular the one-third octave spectrum of the source. On condition that any improved model should use this collected database, a procedure is necessary to estimate these spectra on the basis of CSEL and directivity pattern.

Such an estimation will only yield a rough approach; the one-third octave spectra may be not reliable enough to serve as input data for a single event prediction. However, also the improved model still focuses on the calculation of long term, multiple-source noise predictions for a large area. And there is still no real chance to apply highly sophisticated sound propagation methods. The following example highlights the challenge of calculating a noise contour map considering terrain shielding effects: For a map area of at least 500 km² and a resolution of 250 m, the calculation must take into account 8,000 receiver points and about 1,000 blast sources at 100 different locations. That means that the procedure needs to analyse 8 million of sound paths over hilly terrain with respect to shielding. It is obvious, that the model still must be simple in order to yield fast running programs.

In addition, there are no measured test data for all the variety of weapons and ammunitions. The software suite WinLarm, used by German authorities to calculate such maps, solves this problem by introducing a so-called friendly system in conjunction with a dedicated weapon database sure. This friendly system makes sure, that the program will always provide a reasonable CSEL source level and a directivity pattern also for not measured blasts. This method is published elsewhere /4/. The estimation method for one-third octave spectra actually completes the friendly-system in WinLarm’s Blaster program.

With blast spectra from explosions in air, there are some basic rules: Versus a linear frequency scale, the blast spectrum has a very simple shape, it is a symmetric peak with a certain centre frequency and slope and a well-defined maximum value. The more acoustic energy is involved the more this centre frequency shifts to lower frequencies. In simple models both rules are strongly related to each other. For a certain centre-frequency there is only one slope and one maximum value allowed. Versus a logarithmic frequency scale, i.e. one-third octave spectrum, the level decreases with 30 dB per frequency decade to the lower frequency bands and with 10 dB per frequency decade to the higher frequency bands.

For the estimation procedure introduced here, the so-called Weber-approach is used. In this approach the radius R completely determines the characteristics of the spectrum. This radius is basically the size of the spherical exploding source when it radiates the blast. This geometric interpretation is useful to consider the coherence of the source.

$$S(w) = \frac{P_0}{p}\left[\frac{a}{a^2+w^2} + j\,\frac{w}{a^2+w^2}\right] \qquad \text{eq. (2)}$$

with $a = \frac{3c}{R_0}\sqrt{1+\left(\frac{c}{wR_0}\right)^2}$ and $P_0 = const = 14.4 kPa$

Eq. 2 actually gives the complex Fourier spectrum S(ω) of the blast. Let denote ω the circle frequency, c the speed of sound and R_0 the so-called Weber-radius. Using standard numerical procedures it is easy to calculate the related one-third-octave spectrum and to set-up a numerical procedure to calculate the radius R_0 for a given CSEL in a certain direction.

DISCUSSION

Normally this spectrum is an superior estimation for propagation models than directly measured spectra if the ground effects are not eliminated from the measured spectrum. If uncorrected spectra, for instance measured spectra according to the rules of /3/ are used, these spectra contain decibel error in the order of 10 or more to the value of those frequency band typically affected by the ground dip at 250 m for typical muzzle heights /5/.

Fig. 1 exemplary shows the result of this method for the muzzle blast of an 120 mm gun mounted to a tank. The rectangles indicate the raw measured one-third octave spectrum at 250 m distance at 135° re. line of fire, yielding a CSEL of 116.9 dB. The circles on the dashed line shows the same measurement but without the ground dip for this single shot using an optimised fit to the whole spectrum. The triangles indicate the calculated one-third octave spectrum using only the CSEL of the raw data and the estimation method described above. Both theoretical spectra are very close because for such low-frequency blasts the CSEL is determined by the frequency bands that are – on the average – affected by pressure doubling and cancellation so that the measured CSEL according to the test plan /1/ is a reliable measure for the CSEL of the direct wave. See /5/ for more details about the validation of the test plan. There would be a difference for blasts with lower energy and higher frequencies. From fig. 1 it is obvious that the calculated spectrum is the better choice than the measured spectrum, where pressure doubling at lower frequencies and pressure release at higher frequencies systematically changes the spectrum due to the flat angle of incidence and the soft ground.

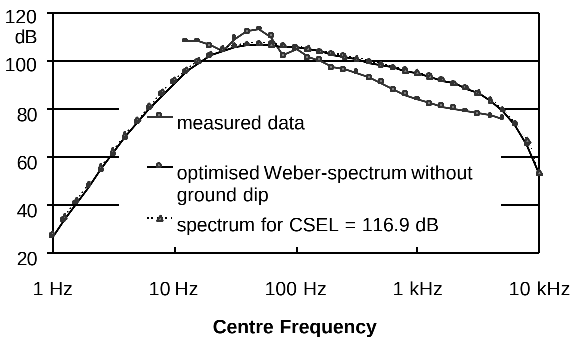

Fig. 1 Raw one-third octave spectrum for a tank shot (rectangles) compared to the predicted spectrum on the basis of its CSEL (triangles) and to spectrum without ground reflection (circles)

Fig. 2 shows the screen shot of the blast select window of the Blaster program of the WinLarm suite. Using the friendly system for the CSEL and the estimation procedure discussed here yields the reference spectrum for the Leopard 2, 120 mm cannon in the same direction as in the example in fig. 1. The spectrum is higher because it is a reference for all ammunitions of the 120 mm gun.

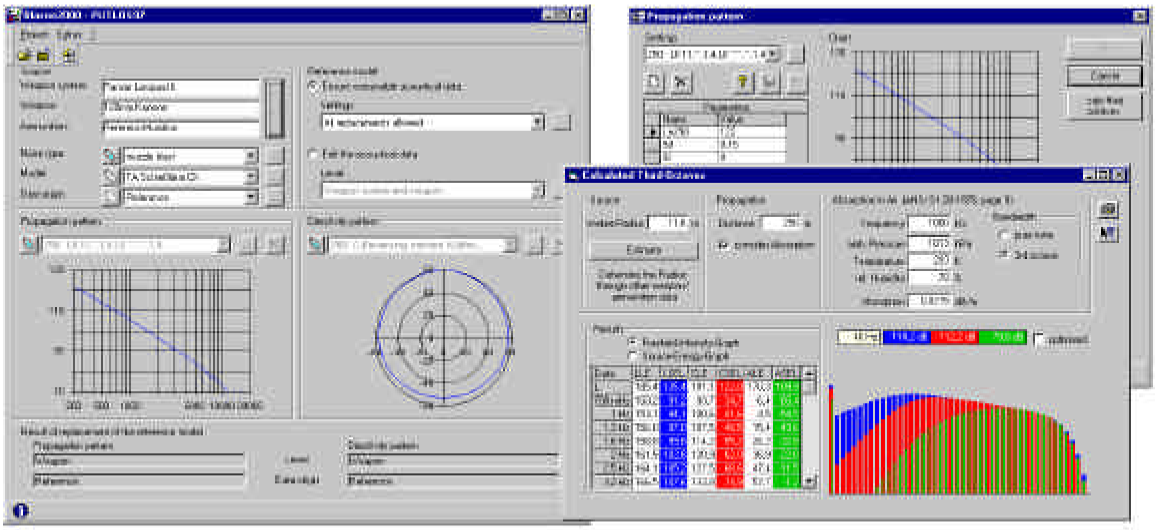

Fig 2. Screen shot of the blast select window of the Blaster program of the WinLarm suite showing the one-third octave spectrum using the CSEL data in WinLarm's database

CONCLUSION

The paper presents a method to estimate one-third octave source spectra for muzzle blast and explosion on the basis source data measured according to the test plan in /3/. In the future, these spectra will be used as input data for an improved noise prediction model for long term average levels from shooting noise in the vicinity of military training areas.

In general, this method is not restricted for heavy weapons and C-weighted levels. It also applies to source data of small arms muzzle blasts that are for example available as A-weighted maximum levels. In the context of small arms, one-third octave spectra are needed to validate procedures according to ISO 9613-2 for these coherent sound sources.

ACKNOWLEDGEMENTS

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